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(54) **INPUT DEVICE HAPTICS AND PRESSURE SENSING**

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(58) **Field of Classification Search**

None

See application file for complete search history.

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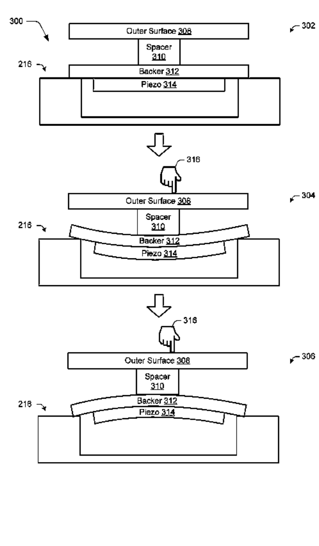
(57) **ABSTRACT**

Input device haptics and pressure sensing techniques are described. An input device includes an outer surface, a pressure sensor and haptic feedback mechanism, and a pressure sensing and haptic feedback module. The outer surface is configured to receive an application of pressure by an object. The pressure sensor and haptic feedback mechanism has one or more piezos configured to detect and quantify an amount of the application of the pressure to the outer surface by the object, the one or more piezos configured to output a signal indicating the quantified amount of the pressure. The pressure sensing and haptic feedback module is configured to receive the signal from the one or more piezos indicating the quantified amount of the pressure and control the haptic feedback of the pressure sensor and haptic feedback mechanism.

20 Claims, 9 Drawing Sheets



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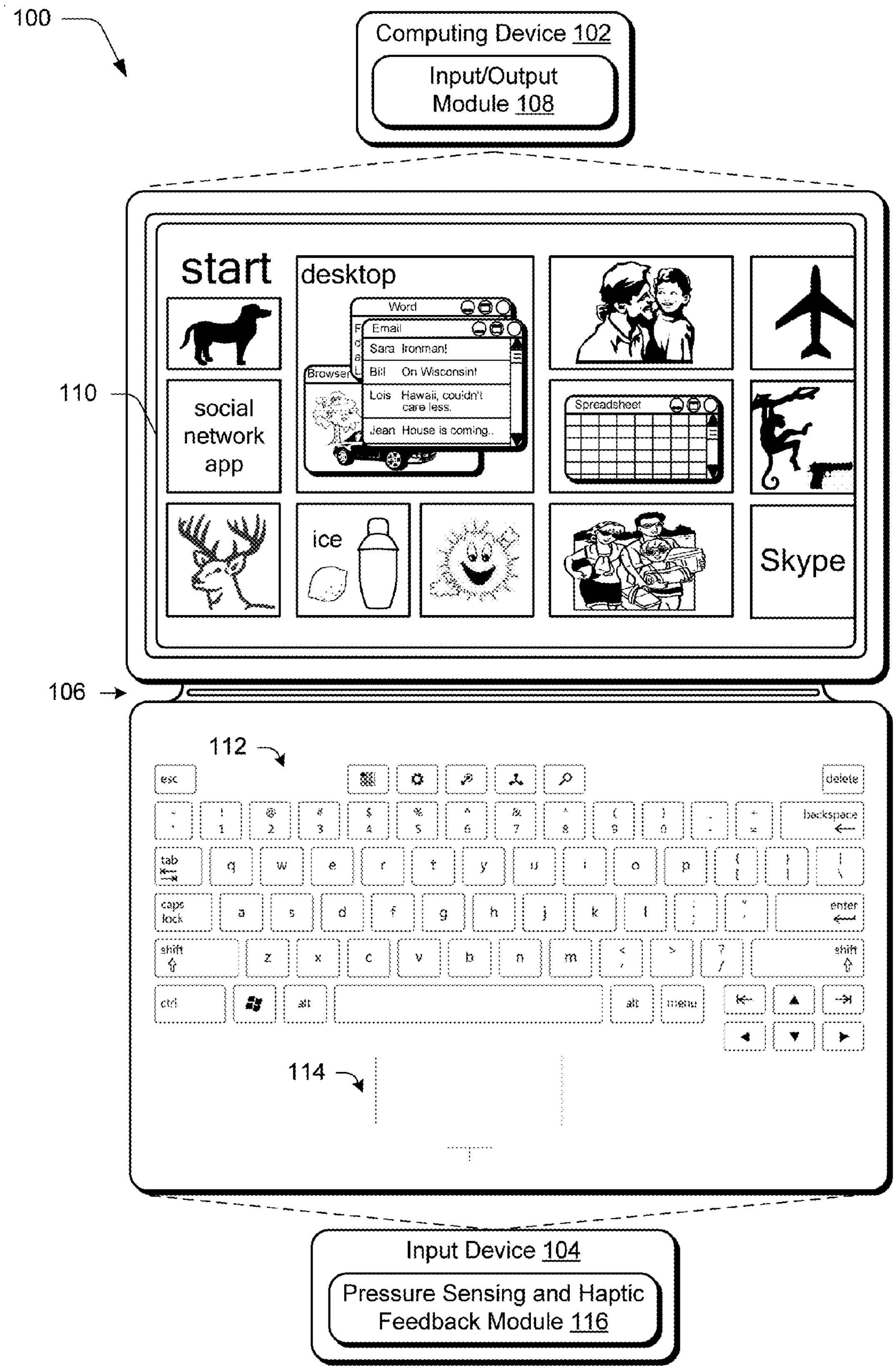
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Fig. 1

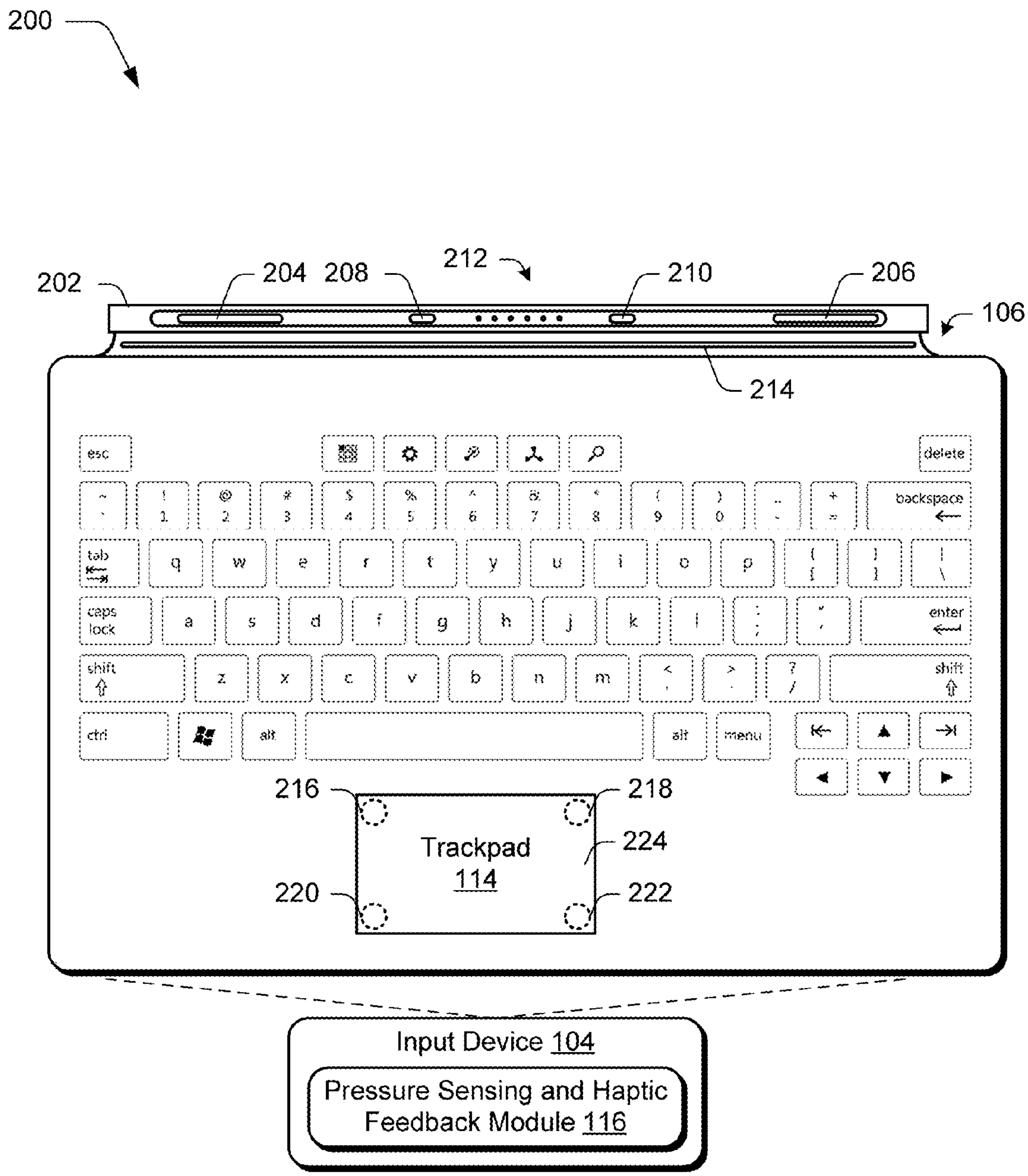
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Fig. 2

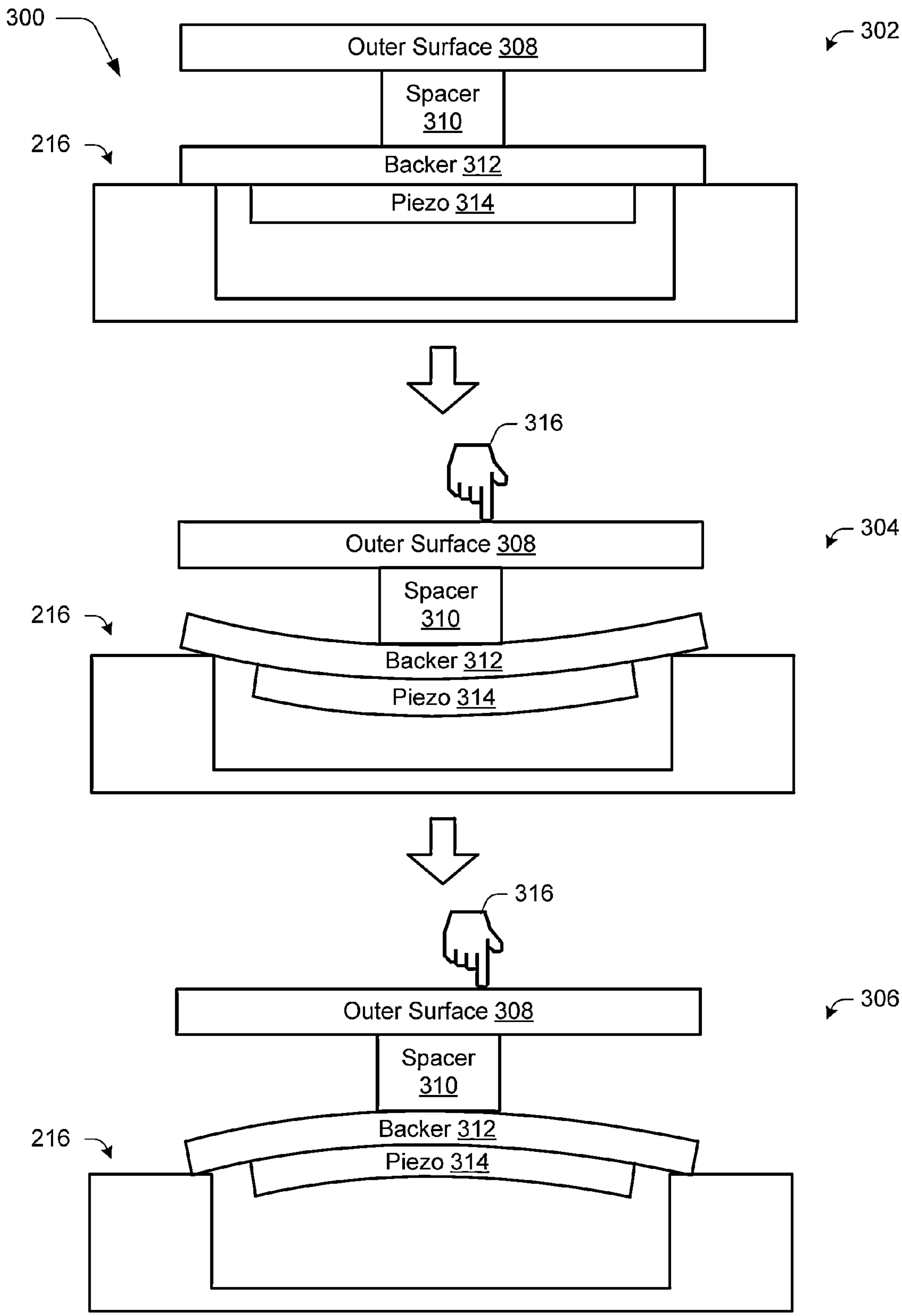
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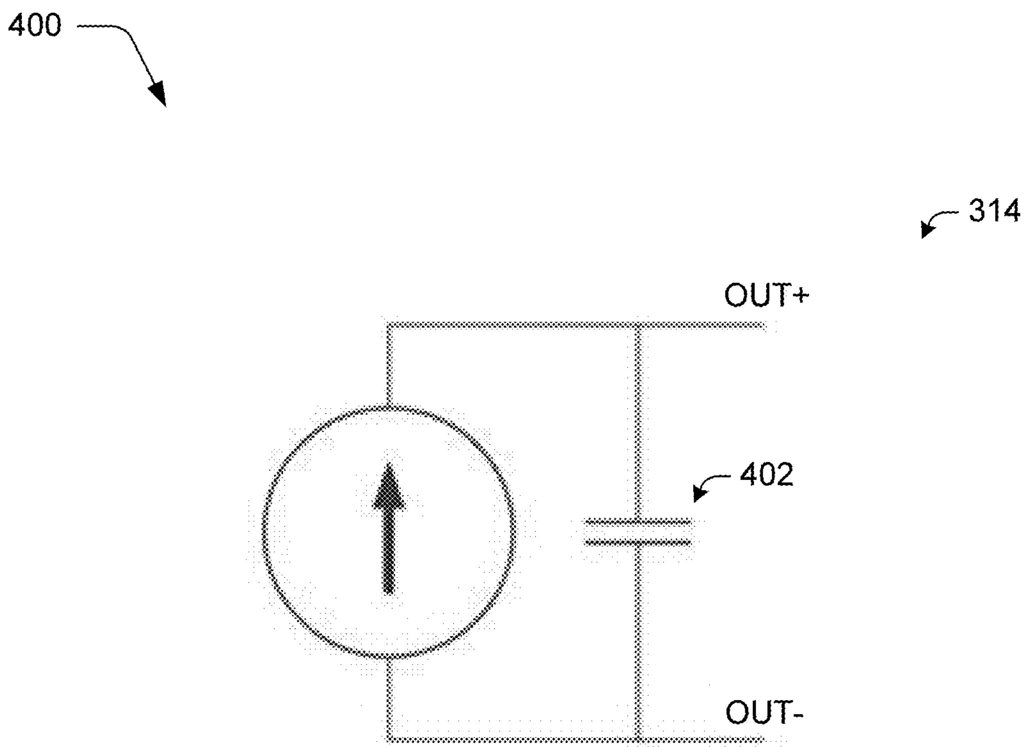
Fig. 3



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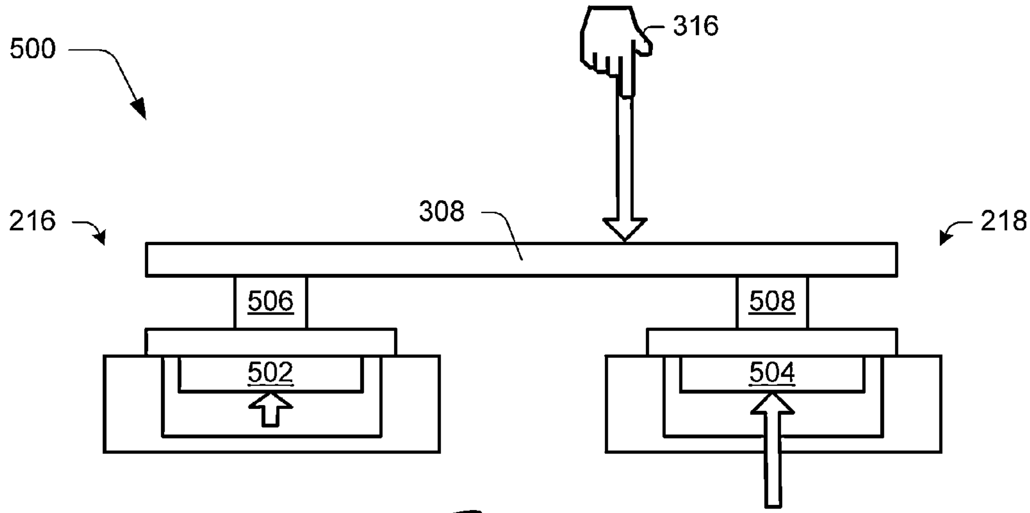

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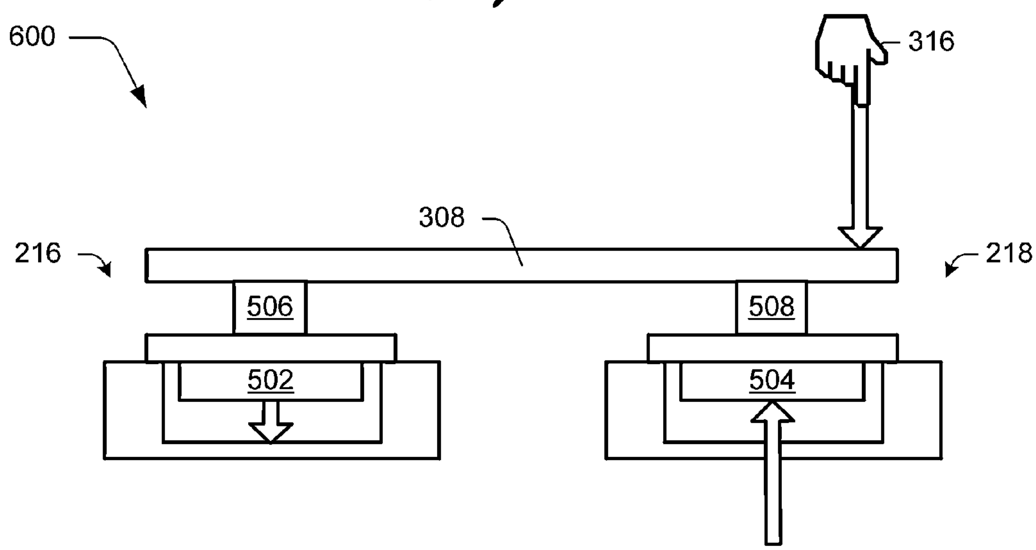

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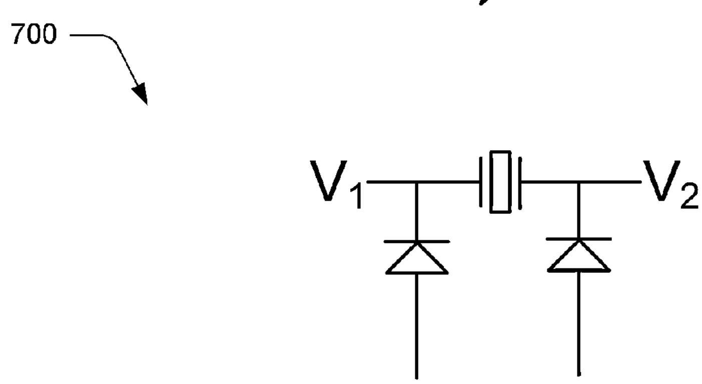

Fig. 7

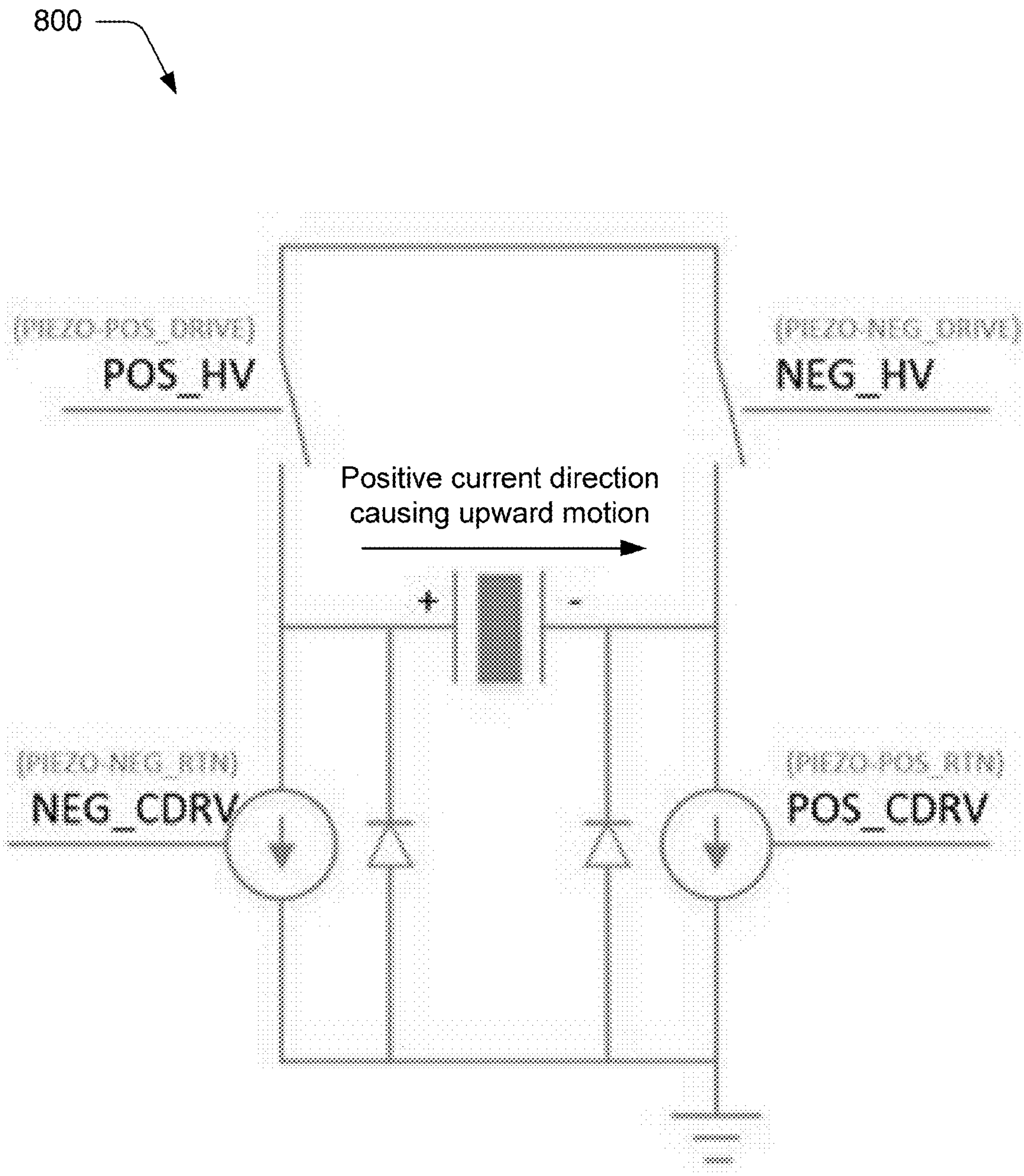
800
(PIEZO-POS_DRIVE)
POS_HV
(PIEZO-NEG_DRIVE)
NEG_HV
Positive current direction
causing upward motion
+
-
(PIEZO-NEG_RTN)
NEG_CDRV
(PIEZO-POS_RTN)
POS_CDRV

Fig. 8

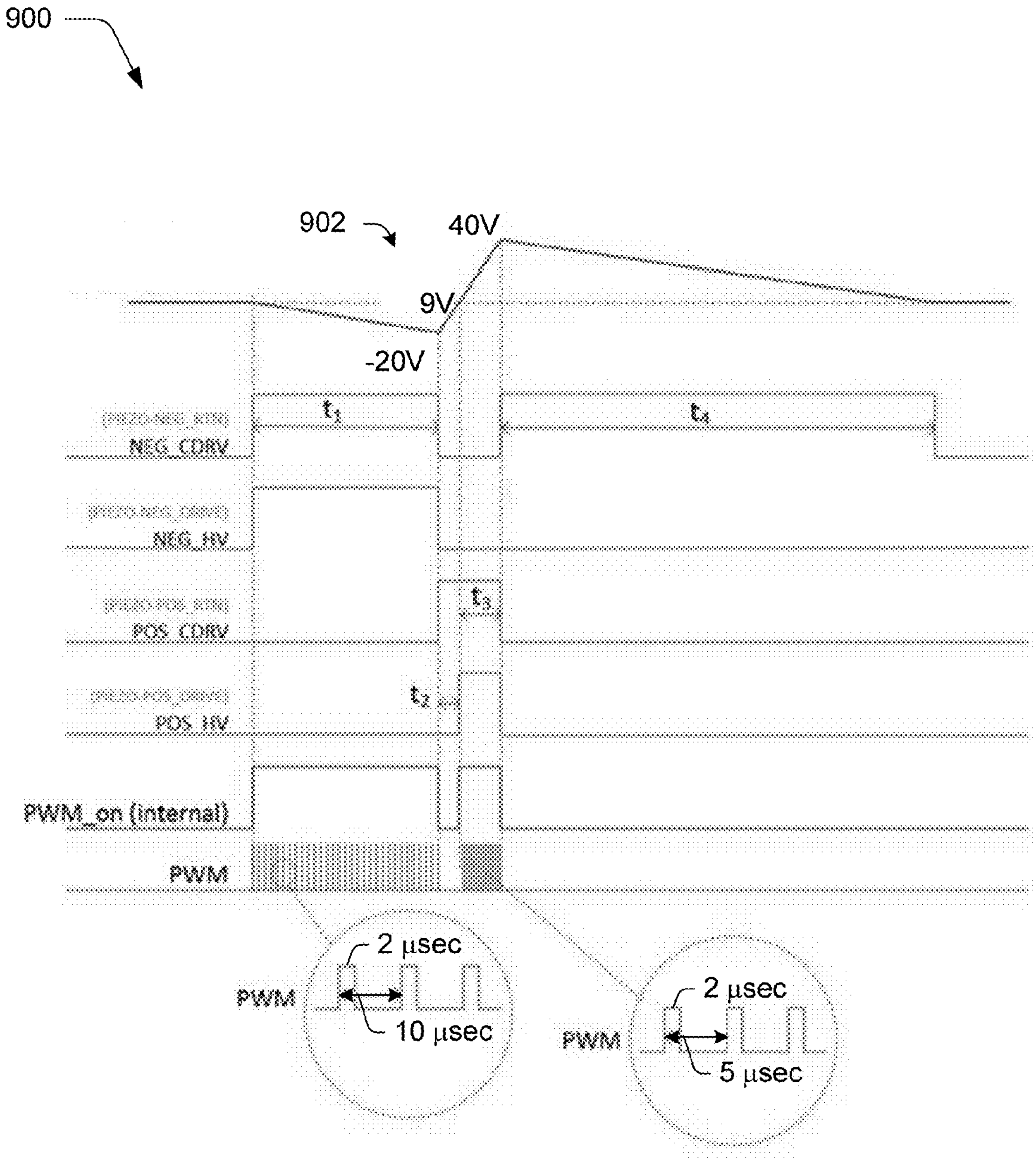
900
902
40V
9V
-20V
t_1
t_4
NEG_CDRV
NEG_HV
t_3
POS_CDRV
t_2
POS_HV
PWM_on (internal)
PWM
PWM
2 μsec
10 μsec
PWM
2 μsec
5 μsec

Fig. 9

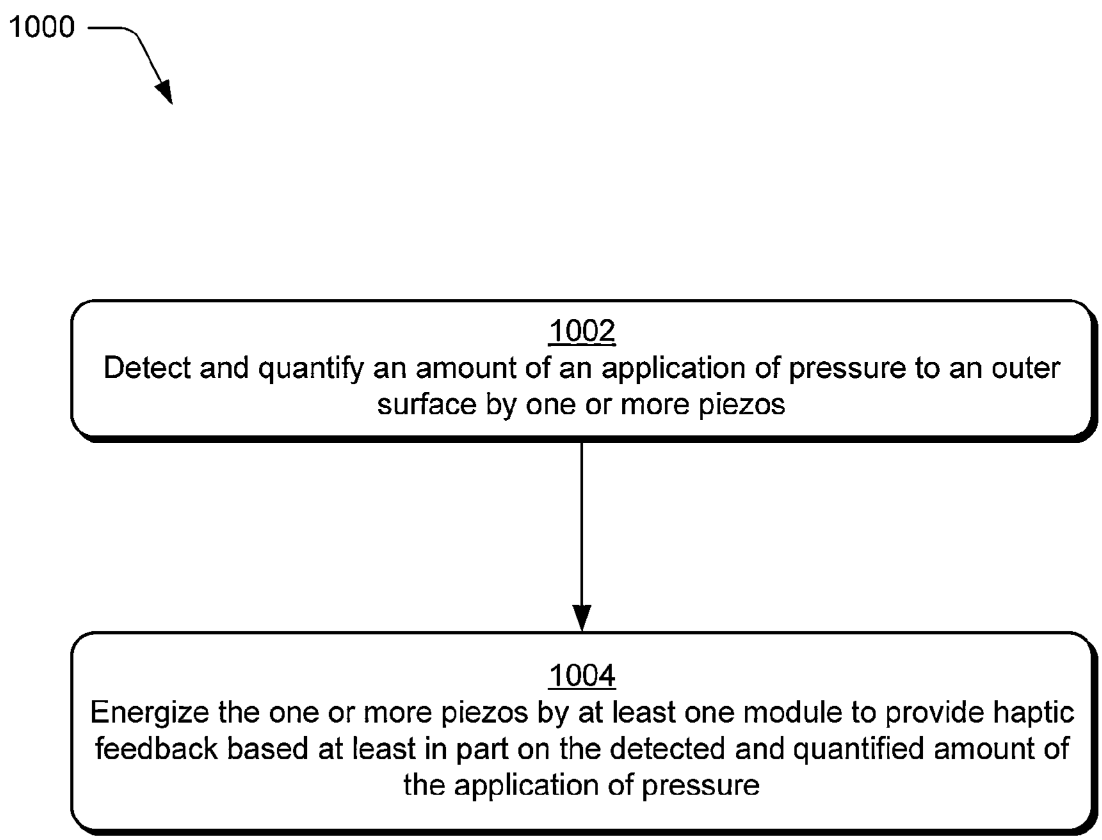
1000
1002
Detect and quantify an amount of an application of pressure to an outer surface by one or more piezos
1004
Energize the one or more piezos by at least one module to provide haptic feedback based at least in part on the detected and quantified amount of the application of pressure

Fig. 10

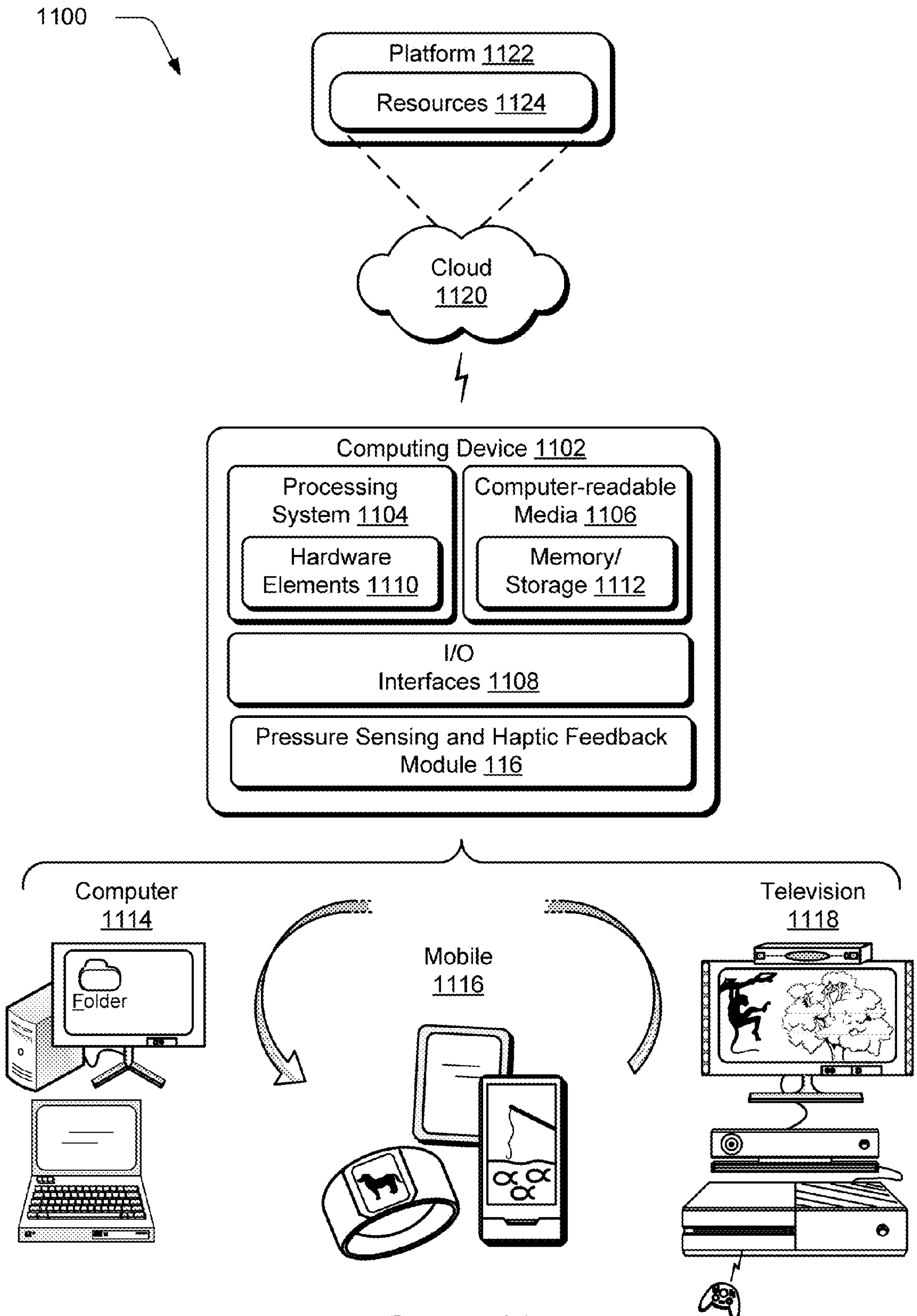
1100
Platform 1122
Resources 1124
Cloud
1120
Computing Device 1102
Processing
System 1104
Computer-readable
Media 1106
Hardware
Elements 1110
Memory/
Storage 1112
I/O
Interfaces 1108
Pressure Sensing and Haptic Feedback
Module 116
Computer
1114
Folder
Mobile
1116
Television
1118

Fig. 11

INPUT DEVICE HAPTICS AND PRESSURE SENSING

This Application claims priority as a continuation-in-part to U.S. patent application Ser. No. 14/144,876, filed Dec. 31, 2013, and titled "Haptic Feedback for Thin User Interfaces," the entire disclosure of which is hereby incorporated by reference.

BACKGROUND

Trackpads may be found on a variety of different devices to support cursor control, such as on a laptop, removable keyboard cover for a tablet, and so on. In some instances, the trackpads also include functionality usable to initiate a selection (e.g., a "click") and thus movement of a cursor and selections may be made by a user without requiring a user to remove a finger from the trackpad to press a separate button.

Conventional techniques used to implement this functionality typically involved a hinged structure and a dome switch. Since these implementations are typically hinged from the top, the response is not uniform and the upper region of the trackpad is difficult to "click." These conventional trackpads also struggle to reject inadvertent actuations when a user is typing, thereby causing a cursor to jump around in a random manner and thus interfere with a user's interaction with a computing device, which is both inefficient and frustrating.

SUMMARY

Input device haptics and pressure sensing techniques are described. In one or more examples, an input device includes an outer surface, a pressure sensor and haptic feedback mechanism, and a pressure sensing and haptic feedback module. The outer surface is configured to receive an application of pressure by an object. The pressure sensor and haptic feedback mechanism has one or more piezos configured to detect and quantify an amount of the application of the pressure to the outer surface by the object, the one or more piezos configured to output a signal indicating the quantified amount of the pressure. The pressure sensing and haptic feedback module is configured to receive the signal from the one or more piezos indicating the quantified amount of the pressure and control the haptic feedback of the pressure sensor and haptic feedback mechanism by energizing the one or more piezos based at least in part of the quantified amount of pressure.

In one or more examples, a trackpad system includes an outer surface configured to receive an application of pressure by an object and detect movement of the object in relation to the outer surface, the detected movement usable to control a cursor of a computing device; a pressure sensor and haptic feedback mechanism having a plurality of piezos that suspend the outer surface and are configured to detect and quantify an amount of the application of the pressure to the outer surface by the object, the pressure sensor and haptic feedback mechanism configured to output one or more signals indicating the quantified amount of the pressure; and a pressure sensing module configured to receive the one or more signals from the pressure sensors indicating the quantified amount of the pressure by the one or more piezos and control the haptic feedback of the haptic feedback mechanism by energizing the one or more piezos based at least in part of the quantified amount of pressure.

In one or more examples, an input device includes an outer surface configured to receive an application of pressure by an object, a pressure sensor configured to detect and quantify an amount of the application of the pressure to the outer surface by the object, the pressure sensor configured to output a signal indicating the quantified amount of the pressure, a haptic feedback mechanism configured to provide haptic feedback using at least one piezo, and a pressure sensing module configured to receive the signal from the pressure sensors indicating the quantified amount of the pressure and control the haptic feedback of the haptic feedback mechanism by energizing the at least one piezo based at least in part of the quantified amount of pressure.

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description is described with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different instances in the description and the figures may indicate similar or identical items. Entities represented in the figures may be indicative of one or more entities and thus reference may be made interchangeably to single or plural forms of the entities in the discussion.

FIG. **1** is an illustration of an environment in an example implementation that is operable that is operable to employ the input device haptics and pressure sensing techniques described herein.

FIG. **2** depicts an example implementation of an input device of FIG. **1** as showing a flexible hinge and trackpad in greater detail.

FIG. **3** depicts an example of a pressure sensor and haptic feedback mechanism of FIG. **2** as employing piezos to detect pressure and/or provide haptic feedback.

FIG. **4** depicts an example circuit model of a piezo of FIG. **3**.

FIG. **5** depicts a cross section view of pressure sensor and haptic feedback mechanisms of FIG. **2**.

FIG. **6** depicts a cross section view of pressure sensor and haptic feedback mechanisms of FIG. **2** as involving negative voltages.

FIG. **7** depicts a circuit in an example implementation that is configured to read bipolar voltages.

FIG. **8** depicts an example implementation of a circuit usable to energize piezos using a bridge circuit.

FIG. **9** depicts an example of a waveform used to drive the circuit shown in FIG. **9**.

FIG. **10** is a flow diagram depicting a procedure in an example implementation in which piezos are used to detect pressure and provide haptic feedback.

FIG. **11** illustrates an example system including various components of an example device that can be implemented as any type of computing device as described with reference to FIGS. **1-10** to implement embodiments of the techniques described herein.

DETAILED DESCRIPTION

Overview

Conventional techniques used to support tactile feedback when "clicking" a trackpad suffered from inadvertent actuations, lack of uniformity in the response, and so forth. Consequently, these conventional techniques could interfere with a user's experience when interacting with the trackpad to input data using the trackpad itself and even a keyboard associated with the trackpad.

Input device haptics and pressure sensing techniques are described. In one or more implementations, an input device such as a trackpad, key of a keyboard, and so forth is configured to support haptics and/or pressure sensing. For example, piezos may be arranged at the corners of a trackpad and as such suspend the trackpad. When a pressure is detected (e.g., a user pressing a surface of the trackpad with a finger), the piezos are energized to provide haptic feedback that may be felt by the user.

Additionally, the piezos may also be utilized to detect the pressure itself, such as to monitor an output voltage of the piezos generated due to strain caused by the pressure to the piezos. In this way, inadvertent clicks may be avoided with a uniform response over an entirety of a surface of the trackpad. A variety of other examples are also contemplated, such as to address voltage decay, bipolar voltages, and so on as described in the following sections and shown in corresponding figures.

In the following discussion, an example environment is first described that may employ the techniques described herein. Example procedures are then described which may be performed in the example environment as well as other environments. Consequently, performance of the example procedures is not limited to the example environment and the example environment is not limited to performance of the example procedures as further described below.

Example Environment

FIG. **1** is an illustration of an environment **100** in an example implementation that is operable to employ the input device haptics and pressure sensing techniques described herein. The illustrated environment **100** includes an example of a computing device **102** that is physically and communicatively coupled to an input device **104** via a flexible hinge **106**. The computing device **102** may be configured in a variety of ways. For example, the computing device **102** may be configured for mobile use, such as a mobile phone, a tablet computer as illustrated, and so on. Thus, the computing device **102** may range from full resource devices with substantial memory and processor resources to a low-resource device with limited memory and/or processing resources. The computing device **102** may also relate to software that causes the computing device **102** to perform one or more operations.

The computing device **102**, for instance, is illustrated as including an input/output module **108**. The input/output module **108** is representative of functionality relating to processing of inputs and rendering outputs of the computing device **102**. A variety of different inputs may be processed by the input/output module **108**, such as inputs relating to functions that correspond to keys of the input device **104**, keys of a virtual keyboard displayed by the display device **110** to identify gestures and cause operations to be performed that correspond to the gestures that may be recognized through the input device **104** and/or touchscreen functionality of the display device **110**, and so forth. Thus, the input/output module **108** may support a variety of different input techniques by recognizing and leveraging a division between types of inputs including key presses, gestures, and so on.

In the illustrated example, the input device **104** is configured as having an input portion that includes a keyboard **112** having a QWERTY arrangement of keys and track pad **114** although other arrangements of keys are also contemplated. Further, other non-conventional configurations are also contemplated, such as a game controller, configuration to mimic a musical instrument, and so forth. Thus, the input device **104** and keys incorporated by the input device **104** may assume a variety of different configurations to support a variety of different functionality.

As previously described, the input device **104** is physically and communicatively coupled to the computing device **102** in this example through use of a flexible hinge **106**. The flexible hinge **106** is flexible in that rotational movement supported by the hinge is achieved through flexing (e.g., bending) of the material forming the hinge as opposed to mechanical rotation as supported by a pin, although that embodiment is also contemplated. Further, this flexible rotation may be configured to support movement in one or more directions (e.g., vertically in the figure) yet restrict movement in other directions, such as lateral movement of the input device **104** in relation to the computing device **102**. This may be used to support consistent alignment of the input device **104** in relation to the computing device **102**, such as to align sensors used to change power states, application states, and so on.

The flexible hinge **106**, for instance, may be formed using one or more layers of fabric and include conductors formed as flexible traces to communicatively couple the input device **104** to the computing device **102** and vice versa. This communication, for instance, may be used to communicate a result of a key press to the computing device **102**, receive power from the computing device, perform authentication, provide supplemental power to the computing device **102**, and so on. The flexible hinge **106** may be configured in a variety of ways, further discussion of which may be found in relation to FIG. **2**.

The input device is also illustrated as including a pressure sensing and haptic feedback module **116** that is representative of functionality to detect pressure and supply haptic feedback in response to the detected pressure. A user, for instance, may press the trackpad with a finger and in response receive haptic feedback. This may be performed in a variety of ways, an example of which is described in the following and shown in a corresponding figure.

FIG. **2** depicts an example implementation **200** of the input device **104** of FIG. **1** as showing the flexible hinge **106** and trackpad **114** in greater detail. In this example, a connection portion **202** of the input device is shown that is configured to provide a communicative and physical connection between the input device **104** and the computing device **102**. The connection portion **202** as illustrated has a height and cross section configured to be received in a channel in the housing of the computing device **102**, although this arrangement may also be reversed without departing from the spirit and scope thereof.

The connection portion **202** is flexibly connected to a portion of the input device **104** that includes the keys through use of the flexible hinge **106**. Thus, when the connection portion **202** is physically connected to the computing device the combination of the connection portion **202** and the flexible hinge **106** supports movement of the input device **104** in relation to the computing device **102** that is similar to a hinge of a book. Through this rotational movement, a variety of different orientations of the input device **104** in relation to the computing device **102** may be supported, such as to act to cover the display device **110** of FIG. **1**, be disposed behind the housing of the computing device **102**, and so forth.

The connection portion **202** is illustrated in this example as including magnetic coupling devices **204**, **206**, mechanical coupling protrusions **208**, **210**, and a plurality of communication contacts **212**. Although physical contacts **212** are shown in this example, wireless communication techniques are also contemplated, e.g., NFC, Bluetooth®, and so forth. The magnetic coupling devices **204**, **206** are configured to magnetically couple to complementary magnetic coupling devices of the computing device **102** through use of one or more magnets. In this way, the input device **104** may be physically secured to the computing device **102** through use of magnetic attraction.

The connection portion **202** also includes mechanical coupling protrusions **208**, **210** to form a mechanical physical connection between the input device **104** and the computing device **102**. The mechanical coupling protrusions **208**, **210** are configured to permit removal of the input device **104** along a plane following a height of the protrusions and restrict removal through mechanical binding along other planes. A mid-spine **214** is also included to support mechanical stiffness and a minimum bend radius of the flexible hinge **106**.

The input device **104** also includes a keyboard **112** and trackpad **114** as previously described. Although the pressure sensing and haptic feedback techniques are described in relation to the trackpad **114** in the following, these techniques are equally applicable to keys of the keyboard **112**.

The trackpad **114** in the illustrated example is formed as a rectangle having four corners, although other shapes are also contemplated. Pressure sensor and haptic feedback mechanisms **216**, **218**, **220**, **222** are disposed at respective corners to suspend an outer surface **224** of the trackpad **114**. The pressure sensor and haptic feedback mechanisms **216-222** are configured to provide haptic feedback based at least in part on sensed amounts of pressure. As such, the pressure sensor and haptic feedback mechanisms **216-222** may be configured in a variety of ways, an example of which is described in the following and shown in a corresponding figure.

FIG. **3** depicts an example **300** of a pressure sensor and haptic feedback mechanism **216** of FIG. **2** as employing piezos to detect pressure and/or provide haptic feedback. This example is illustrated using first, second, and third stages **302**, **304**, **306**. The pressure sensor and haptic feedback mechanism **216** includes an outer surface **308**, such as an outer surface **308** of the trackpad, a key of a keyboard, and so forth. The outer surface **308** may be formed from a variety of different materials and combinations thereof, such as a glass, plastic, a laminate structure, include a fabric outer layer, and so forth.

The outer surface **308** is coupled mechanically to a spacer **310** that is coupled mechanically to a backer **312**. The spacer **310** is configured to channel pressure applied to the outer surface **310** to a central region of the backer **312** and thus a piezo **314** connected thereto. In this way, an amount of deflection of the backer **312** and corresponding piezo **314** is increased in response to the pressure even on "off center" presses, thereby supporting a greater sensitivity to detection of an amount of pressure and haptic response.

The backer **312** is formed from a rigid material (e.g., steel, plastic, and the like) and physically coupled to the piezo **314**. Accordingly, when a pressure is not applied to the outer surface **308** (and thus no pressure is applied to the backer **312**) the piezo **314** is not strained and as such does not output a voltage as shown at the first stage **302**. At the second stage **304**, an object **316** such as a finger of a user's hand (not shown in scale) as part of pressing down on the outer surface **316** applies a pressure that causes deflection of the backer **312** and thus strain on the piezo **314** which results in an output voltage which is detectable by the pressure sensing and haptic feedback module **116**.

As the voltage output by the piezo **314** changes with an amount of pressure applied, the piezo **314** is configured to detect not just presence or absence or pressure, but also an amount of pressure, e.g., a respective one of a plurality of levels of pressure. The piezo **314** is configurable in a variety of ways, such as formed at least in part from a piezo ceramic material, PZT, electroactive polymer, or electromechanical polymer. Other techniques to detect pressure are also contemplated, such as FSRs, changing in capacitance, changes in detect contact size, strain gauges, piezo-resistive elements, and so on.

The piezo **314** is also usable to provide a haptic feedback as shown at the third stage **306**. Continuing with the previous example in the second stage **304**, the piezo **314** detects an amount of pressure applied to the outer surface **308** by the finger of the user's hand. If the detected pressure is over a threshold, the pressure sensing and haptic feedback module **116** energizes the piezo **314**. This causes the piezo **314** to pull against the backer **312** and thus deflect outward back toward an object **316** applying the pressure, thereby providing a haptic response.

In this way, the piezo **314** is leveraged to provide both pressure sensing and haptic feedback. Other examples are also contemplated. For instance, pressure may be sensed by a pressure sensor that is not the piezo and then the piezo may be used to provide haptic feedback. In another instance, a first piezo may be used to detect pressure and another piezo may be used to provide haptic feedback.

FIG. **4** depicts an example circuit model **400** of the piezo **314** of FIG. **3**. When the piezo **314** deflects as shown in the second stage **304** of FIG. **3**, a current is generated, which then charges its intrinsic capacitance as well as any externally applied capacitance. The voltage across the capacitor **402** can then be read by the pressure sensing and haptic feedback module **116** as an indication of deflection, and thus applied pressure.

FIG. **5** depicts a cross section view **500** of pressure sensor and haptic feedback mechanisms **216**, **218** of FIG. **2**. When there are multiple pressure sensor and haptic feedback mechanisms **216-222** as shown in FIG. **2**, measures of signals generated by the mechanisms may be taken in a variety of different ways. For example, each of the mechanisms may be measured individually, which may be used to calculate a location (e.g., centroid) of an object that applies the pressure in relation to the outer surface **308**, e.g., through triangulation.

In another example, the signal is derived by summing signals from all of the pressure sensor and haptic feedback mechanisms **216-222**, i.e., the piezos of these mechanisms. As shown in FIG. **5**, for instance, an object **216** applies pressure that is detected by respective piezos **502**, **504** of respective pressure sensor and haptic feedback mechanisms **216**, **218**. The pressure is applied by the object **316** in this example between spacers **506**, **508** of the mechanisms.

Arrows are utilized to indicate application of the pressure by the object **316** and respective amounts of the pressure sensed by the piezos **502**, **504**. As illustrated, the piezo **504** closest to a location at which the pressure is applied receives a larger amount of the pressure than the piezo **502** that is located further away. By summing the responses of the piezos in this example, the amount of pressure applied by the object **316** is detected.

FIG. **6** depicts a cross section view **600** of pressure sensor and haptic feedback mechanisms **216**, **218** of FIG. **2** as involving negative voltages. In this example, the object **316** applies pressure to an area of the outer surface **308** that is not positioned between the spacers **506**, **508** of the pressure sensor and haptic feedback mechanisms **216**, **218**. This causes the piezo **502** to "lift up" and exhibit a negative voltage while the piezo **504** measures a positive voltage. In this example, the voltages from the piezos **502**, **504** are still summed to detect the amount of pressure applied by the object **316** as the amount of pressure detected by the piezo **504** more than compensates for the negative amount of pressure detected by the piezo **502**.

Returning again to FIG. **4**, techniques are employed to reduce an effect of charge leakage. Once charged, the capacitor **402** slowly leaks away charge. Accordingly, if a user wants to perform a "push and hold" gesture, the voltage may slowly drain away to the point where the system could believe that a user has lifted their finger away from the outer surface, even though the finger is applying a relatively constant amount of pressure. By periodically discharging the capacitor **402** and storing pressure offsets (e.g., by the pressure sensing and haptic feedback module **116**), this issue of decay can be avoided.

For example, when a piezo is unmoving, current does not flow and the voltage is held. At any time, the capacitor **402** of the circuit **400** can be discharged by an external circuit, e.g., by the pressure sensing and haptic feedback module **116**. Any additional deflection, whether positive or negative, for the piezo will then charge the capacitor from its discharged state.

One example of such a sequence is for a finger to apply a pressure to a piezo and hold, causing the piezo to generate a signal of "X" volts, which is stored as an off-set. The capacitor **402** is then discharged by an external circuit (e.g., pressure sensing and haptic feedback module **116**) such that the piezo voltage is now "0." Accordingly, the piezo voltage is now zero volts, but the "X" offset is remembered and stored in "Y" such that pressure now equals a currently read voltage plus a value stored in "Y." Therefore, if the finger ceases application of pressure (i.e., releases the piezo) and the piezo relaxes to a rest deflection, the piezo voltage is now "−X" volts. With the stored away offset, however, the pressure is read as zero by the pressure sensing and haptic feedback module **116**. The capacitor **402** is discharged again and zero is stored as the new offset.

In one or more implementations, discharge of the capacitor **402** is managed to occur when above a threshold voltage and when pressure has been relatively constant for a defined amount of time. In this way, risk of injecting noise into the pressure signal is minimized.

In order to provide haptic feedback as previously described, the pressure sensing and haptic feedback module **116** energizes the piezos, e.g., through application of +/−one hundred volts. However, after the piezos are energized the amount of voltage remaining in the piezos is random. Accordingly, in order to continue to use the piezos for pressure sensing after a haptic event, an amount of pressure is detected and stored in an offset that includes a sum of a piezo voltage "X" and accumulated offsets "Y" as described above.

The haptic event is performed by energizing the piezos by the pressure sensing and haptic feedback module **116**. The piezos are cleared and a waiting period is undertaken for an amount of time in order to settle voltages of the piezos. The voltage is then read, and the offset "Y" is set such that a read-back pressure matches a pressure before the haptic event. Accordingly, in this example an assumption is made that the pressure going into a haptic event matches the pressure coming out of the haptic event such that after the haptic event the pressure is recalibrated to match the previous pressure before the event.

To keep the system calibrated, the pressure sensing and haptic feedback module **116** may zero the piezos by defining a read-back voltage as zero pressure, which optionally involves clearing the piezos when it is sensed that the pressure is removed, e.g., the object is lifted from the outer surface. This lifting may be detected using sensors (e.g., capacitive sensors) of the trackpad that are used to detect movement and location.

FIG. **7** depicts a circuit **700** in an example implementation that is configured to read bipolar voltages. As described in relation to FIG. **6** above, in some instances positive and negative voltages may be detected by the pressure sensor and haptic feedback mechanisms **216**, **218**. In order to establish a zero point as actually occurring at a zero voltage, the voltage is measure differentially using diodes as shown in the circuit **700** of FIG. **7**. An ADC may be connected to either terminal, which may be represented as capacitors to ground.

FIG. **8** depicts an example implementation of a circuit **800** usable to energize piezos using a bridge circuit. An example of a waveform **900** used to drive the circuit **800** is shown in FIG. **9**. The haptic response (i.e., the "click sensation") occurs at a rapid ramp up **902** portion of the waveform **900** at times "t**2**" and "t**3**." In this way, piezos may be used to detect applied pressure and provide haptic feedback, further discussion of which is included in the following procedure.

Example Procedures

The following discussion describes haptic and pressure sensing techniques that may be implemented utilizing the previously described systems and devices. Aspects of each of the procedures may be implemented in hardware, firmware, or software, or a combination thereof. The procedures are shown as a set of blocks that specify operations performed by one or more devices and are not necessarily limited to the orders shown for performing the operations by the respective blocks. In portions of the following discussion, reference will be made to the figures described above.

Functionality, features, and concepts described in relation to the examples of FIGS. **1-9** may be employed in the context of the procedures described herein. Further, functionality, features, and concepts described in relation to different procedures below may be interchanged among the different procedures and are not limited to implementation in the context of an individual procedure. Moreover, blocks associated with different representative procedures and corresponding figures herein may be applied together and/or combined in different ways. Thus, individual functionality, features, and concepts described in relation to different example environments, devices, components, and procedures herein may be used in any suitable combinations and are not limited to the particular combinations represented by the enumerated examples.

FIG. **10** depicts a procedure **1000** in an example implementation in which piezos are used to detect pressure and provide haptic feedback. An amount of an application of pressure to an outer surface is detected and quantified by one or more piezos (block **1002**). The one or more piezos are energized by at least one module to provide haptic feedback based at least in part on the detected and quantified amount of the application of pressure (block **1004**). A variety of other examples are also contemplated.

Example System and Device

FIG. **11** illustrates an example system generally at **1100** that includes an example computing device **1102** that is representative of one or more computing systems and/or devices that may implement the various techniques described herein. This is illustrated through inclusion of the pressure sensing and haptic feedback module **116**. The computing device **1102** may be, for example, a server of a service provider, a device associated with a client (e.g., a client device), an on-chip system, and/or any other suitable computing device or computing system.

The example computing device **1102** as illustrated includes a processing system **1104**, one or more computer-readable media **1106**, and one or more I/O interface **1108** that are communicatively coupled, one to another. Although not shown, the computing device **1102** may further include a system bus or other data and command transfer system that couples the various components, one to another. A system bus can include any one or combination of different bus structures, such as a memory bus or memory controller, a peripheral bus, a universal serial bus, and/or a processor or local bus that utilizes any of a variety of bus architectures. A variety of other examples are also contemplated, such as control and data lines.

The processing system **1104** is representative of functionality to perform one or more operations using hardware. Accordingly, the processing system **1104** is illustrated as including hardware element **1110** that may be configured as processors, functional blocks, and so forth. This may include implementation in hardware as an application specific integrated circuit or other logic device formed using one or more semiconductors. The hardware elements **1110** are not limited by the materials from which they are formed or the processing mechanisms employed therein. For example, processors may be comprised of semiconductor(s) and/or transistors (e.g., electronic integrated circuits (ICs)). In such a context, processor-executable instructions may be electronically-executable instructions.

The computer-readable storage media **1106** is illustrated as including memory/storage **1112**. The memory/storage **1112** represents memory/storage capacity associated with one or more computer-readable media. The memory/storage component **1112** may include volatile media (such as random access memory (RAM)) and/or nonvolatile media (such as read only memory (ROM), Flash memory, optical disks, magnetic disks, and so forth). The memory/storage component **1112** may include fixed media (e.g., RAM, ROM, a fixed hard drive, and so on) as well as removable media (e.g., Flash memory, a removable hard drive, an optical disc, and so forth). The computer-readable media **1106** may be configured in a variety of other ways as further described below.

Input/output interface(s) **1108** are representative of functionality to allow a user to enter commands and information to computing device **1102**, and also allow information to be presented to the user and/or other components or devices using various input/output devices. Examples of input devices include a keyboard, a cursor control device (e.g., a mouse), a microphone, a scanner, touch functionality (e.g., capacitive or other sensors that are configured to detect physical touch), a camera (e.g., which may employ visible or non-visible wavelengths such as infrared frequencies to recognize movement as gestures that do not involve touch), and so forth. Examples of output devices include a display device (e.g., a monitor or projector), speakers, a printer, a network card, tactile-response device, and so forth. Thus, the computing device **1102** may be configured in a variety of ways as further described below to support user interaction.

Various techniques may be described herein in the general context of software, hardware elements, or program modules. Generally, such modules include routines, programs, objects, elements, components, data structures, and so forth that perform particular tasks or implement particular abstract data types. The terms "module," "functionality," and "component" as used herein generally represent software, firmware, hardware, or a combination thereof. The features of the techniques described herein are platform-independent, meaning that the techniques may be implemented on a variety of commercial computing platforms having a variety of processors.

An implementation of the described modules and techniques may be stored on or transmitted across some form of computer-readable media. The computer-readable media may include a variety of media that may be accessed by the computing device **1102**. By way of example, and not limitation, computer-readable media may include "computer-readable storage media" and "computer-readable signal media."

"Computer-readable storage media" may refer to media and/or devices that enable persistent and/or non-transitory storage of information in contrast to mere signal transmission, carrier waves, or signals per se. Thus, computer-readable storage media refers to non-signal bearing media. The computer-readable storage media includes hardware such as volatile and non-volatile, removable and non-removable media and/or storage devices implemented in a method or technology suitable for storage of information such as computer readable instructions, data structures, program modules, logic elements/circuits, or other data. Examples of computer-readable storage media may include, but are not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, hard disks, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or other storage device, tangible media, or article of manufacture suitable to store the desired information and which may be accessed by a computer.

"Computer-readable signal media" may refer to a signal-bearing medium that is configured to transmit instructions to the hardware of the computing device **1102**, such as via a network. Signal media typically may embody computer readable instructions, data structures, program modules, or other data in a modulated data signal, such as carrier waves, data signals, or other transport mechanism. Signal media also include any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media include wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared, and other wireless media.

As previously described, hardware elements **1110** and computer-readable media **1106** are representative of modules, programmable device logic and/or fixed device logic implemented in a hardware form that may be employed in some embodiments to implement at least some aspects of the techniques described herein, such as to perform one or more instructions. Hardware may include components of an integrated circuit or on-chip system, an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a complex programmable logic device (CPLD), and other implementations in silicon or other hardware. In this context, hardware may operate as a processing device that performs program tasks defined by instructions and/or logic embodied by the hardware as well as a hardware utilized to store instructions for execution, e.g., the computer-readable storage media described previously.

Combinations of the foregoing may also be employed to implement various techniques described herein. Accordingly, software, hardware, or executable modules may be implemented as one or more instructions and/or logic embodied on some form of computer-readable storage media and/or by one or more hardware elements **1110**. The computing device **1102** may be configured to implement particular instructions and/or functions corresponding to the software and/or hardware modules. Accordingly, implementation of a module that is executable by the computing device **1102** as software may be achieved at least partially in hardware, e.g., through use of computer-readable storage media and/or hardware elements **1110** of the processing system **1104**. The instructions and/or functions may be executable/operable by one or more articles of manufacture (for example, one or more computing devices **1102** and/or processing systems **1104**) to implement techniques, modules, and examples described herein.

As further illustrated in FIG. **11**, the example system **1100** enables ubiquitous environments for a seamless user experience when running applications on a personal computer (PC), a television device, and/or a mobile device. Services and applications run substantially similar in all three environments for a common user experience when transitioning from one device to the next while utilizing an application, playing a video game, watching a video, and so on.

In the example system **1100**, multiple devices are interconnected through a central computing device. The central computing device may be local to the multiple devices or may be located remotely from the multiple devices. In one embodiment, the central computing device may be a cloud of one or more server computers that are connected to the multiple devices through a network, the Internet, or other data communication link.

In one embodiment, this interconnection architecture enables functionality to be delivered across multiple devices to provide a common and seamless experience to a user of the multiple devices. Each of the multiple devices may have different physical requirements and capabilities, and the central computing device uses a platform to enable the delivery of an experience to the device that is both tailored to the device and yet common to all devices. In one embodiment, a class of target devices is created and experiences are tailored to the generic class of devices. A class of devices may be defined by physical features, types of usage, or other common characteristics of the devices.

In various implementations, the computing device **1102** may assume a variety of different configurations, such as for computer **1114**, mobile **1116**, and television **1118** uses. Each of these configurations includes devices that may have generally different constructs and capabilities, and thus the computing device **1102** may be configured according to one or more of the different device classes. For instance, the computing device **1102** may be implemented as the computer **1114** class of a device that includes a personal computer, desktop computer, a multi-screen computer, laptop computer, netbook, and so on.

The computing device **1102** may also be implemented as the mobile **1116** class of device that includes mobile devices, such as a mobile phone, wearables (e.g., wrist bands, pendants, rings, etc.) portable music player, portable gaming device, a tablet computer, a multi-screen computer, and so on. The computing device **1102** may also be implemented as the television **1118** class of device that includes devices having or connected to generally larger screens in casual viewing environments. These devices include televisions, set-top boxes, gaming consoles, and so on. Other devices are also contemplated, such as appliances, thermostats and so on as part of the "Internet of Things."

The techniques described herein may be supported by these various configurations of the computing device **1102** and are not limited to the specific examples of the techniques described herein. This functionality may also be implemented all or in part through use of a distributed system, such as over a "cloud" **1120** via a platform **1122** as described below.

The cloud **1120** includes and/or is representative of a platform **1122** for resources **1124**. The platform **1122** abstracts underlying functionality of hardware (e.g., servers) and software resources of the cloud **1120**. The resources **1124** may include applications and/or data that can be utilized while computer processing is executed on servers that are remote from the computing device **1102**. Resources **1124** can also include services provided over the Internet and/or through a subscriber network, such as a cellular or Wi-Fi network.

The platform **1122** may abstract resources and functions to connect the computing device **1102** with other computing devices. The platform **1122** may also serve to abstract scaling of resources to provide a corresponding level of scale to encountered demand for the resources **1124** that are implemented via the platform **1122**. Accordingly, in an interconnected device embodiment, implementation of functionality described herein may be distributed throughout the system **1100**. For example, the functionality may be implemented in part on the computing device **1102** as well as via the platform **1122** that abstracts the functionality of the cloud **1120**.

Conclusion and Example Implementations

Example implementations described herein include, but are not limited to, one or any combinations of one or more of the following examples:

In one or more examples, an input device includes an outer surface, a pressure sensor and haptic feedback mechanism, and a pressure sensing and haptic feedback module. The outer surface is configured to receive an application of pressure by an object. The pressure sensor and haptic feedback mechanism has one or more piezos configured to detect and quantify an amount of the application of the pressure to the outer surface by the object, the one or more piezos configured to output a signal indicating the quantified amount of the pressure. The pressure sensing and haptic feedback module is configured to receive the signal from the one or more piezos indicating the quantified amount of the pressure and control the haptic feedback of the pressure sensor and haptic feedback mechanism by energizing the one or more piezos based at least in part of the quantified amount of pressure.

An example as described alone or in combination with any of the other examples described above or below, wherein the pressure sensor and haptic feedback mechanism includes a backer that deflects in response to a pulling motion of the one or more piezos due to the energizing of the one or more piezos.

An example as described alone or in combination with any of the other examples described above or below, further comprising a spacer configured to route the amount of pressure applied to the outer surface for application at a generally central region of the backer.

An example as described alone or in combination with any of the other examples described above or below, wherein the outer surface is formed as part of a trackpad that includes one or more sensors disposed thereon that are configured to detect proximity and movement of the object in relation to the outer surface.

An example as described alone or in combination with any of the other examples described above or below, wherein the one or more piezos are formed at least in part from a piezo ceramic material, PZT, electroactive polymer, or electromechanical polymer.

An example as described alone or in combination with any of the other examples described above or below, wherein the pressure sensing module includes a capacitor that takes as an input the signal from the one or more piezos, the capacitor is configured to be reset to address voltage decay of the signal using a stored voltage offset by the pressure sensing and haptic feedback module.

In one or more examples, a trackpad system includes an outer surface configured to receive an application of pressure by an object and detect movement of the object in relation to the outer surface, the detected movement usable to control a cursor of a computing device; a pressure sensor and haptic feedback mechanism having a plurality of pressure sensors that suspend the outer surface and are configured to detect and quantify an amount of the application of the pressure to the outer surface by the object, the pressure sensor and haptic feedback mechanism configured to output one or more signals indicating the quantified amount of the pressure; and a pressure sensing module configured to receive the one or more signals from the plurality of pressure sensors indicating the quantified amount of the pressure by the one or more piezos and control haptic feedback of the haptic feedback mechanism by energizing one or more piezos based at least in part on the quantified amount of pressure.

An example as described alone or in combination with any of the other examples described above or below, wherein the plurality of pressure sensors utilize the one or more piezos to detect and quantify the amount of the application of pressure.

An example as described alone or in combination with any of the other examples described above or below, wherein the one or more signals are summed from the plurality of pressure sensors.

An example as described alone or in combination with any of the other examples described above or below, wherein the one or more signals are received individually by the pressure sensing module from respective ones of the plurality of pressure sensors.

An example as described alone or in combination with any of the other examples described above or below, wherein the individually received signals are usable to determine a relative location of the object in relation to the outer surface by the pressure sensing module.

An example as described alone or in combination with any of the other examples described above or below, wherein the individually received signals include bipolar voltages that are measured differentially using diodes of the pressure sensing module.

An example as described alone or in combination with any of the other examples described above or below, wherein the pressure sensing module includes a capacitor that takes as an input the signal from the plurality of pressure sensors, the capacitor configured to be reset as part of the pressure sensing module to address voltage decay of the signal using a stored voltage offset.

In one or more examples, a trackpad system includes an outer surface configured to receive an application of pressure by an object and detect movement of the object in relation to the outer surface, the detected movement usable to control a cursor of a computing device; a pressure sensor and haptic feedback mechanism having a plurality of piezos that suspend the outer surface and are configured to detect and quantify an amount of the application of the pressure to the outer surface by the object, the pressure sensor and haptic feedback mechanism configured to output one or more signals indicating the quantified amount of the pressure; and a pressure sensing module configured to receive the one or more signals from the pressure sensors indicating the quantified amount of the pressure by the one or more piezos and control the haptic feedback of the haptic feedback mechanism by energizing the one or more piezos based at least in part of the quantified amount of pressure.

An example as described alone or in combination with any of the other examples described above or below, wherein the outer surface has a plurality of corners and the plurality of piezos are disposed at respective ones of the plurality of corners.

An example as described alone or in combination with any of the other examples described above or below, wherein the one or more signals are summed from the plurality of piezos.

An example as described alone or in combination with any of the other examples described above or below, wherein the one or more signals are received individually by the pressure sensing module from respective ones of the plurality of piezos.

An example as described alone or in combination with any of the other examples described above or below, wherein the individually received signals are usable to determine a relative location of the object in relation to the outer surface by the pressure sensing module.

An example as described alone or in combination with any of the other examples described above or below, wherein the individually received signals include bipolar voltages that are measured differentially using diodes of the pressure sensing module.

An example as described alone or in combination with any of the other examples described above or below, wherein the pressure sensing module includes a capacitor that takes as an input the signal from the pressure sensor, the capacitor is configured to be reset as part of the pressure sensing module to address voltage decay of the signal using a stored voltage offset.

In one or more examples, an input device includes an outer surface configured to receive an application of pressure by an object, a pressure sensor configured to detect and quantify an amount of the application of the pressure to the outer surface by the object, the pressure sensor configured to output a signal indicating the quantified amount of the pressure, a haptic feedback mechanism configured to provide haptic feedback using at least one piezo, and a pressure sensing module configured to receive the signal from the pressure sensors indicating the quantified amount of the pressure and control the haptic feedback of the haptic feedback mechanism by energizing the at least one piezo based at least in part of the quantified amount of pressure.

An example as described alone or in combination with any of the other examples described above or below, wherein the pressure sensor employs the at least one piezo of the haptic feedback mechanism to detect and quantify the amount of the application of the pressure.

An example as described alone or in combination with any of the other examples described above or below, wherein the haptic feedback mechanism includes a backer that deflects in response to a pulling motion of the at least one piezo due to the energizing of the at least one piezo.

An example as described alone or in combination with any of the other examples described above or below, further comprising a spacer configured to route the amount of pressure applied to the outer surface for application at a generally central region of the backer.

An example as described alone or in combination with any of the other examples described above or below, wherein the outer surface is formed as part of a trackpad that includes one or more sensors disposed thereon that are configured to detect proximity and movement of the object in relation to the outer surface.

An example as described alone or in combination with any of the other examples described above or below, wherein the at least one piezo is formed at least in part from a piezo ceramic material, PZT, electroactive polymer, or electromechanical polymer.

An example as described alone or in combination with any of the other examples described above or below, wherein the pressure sensing module includes a capacitor that takes as an input the signal from the pressure sensor, the capacitor is configured to be reset as part of the pressure sensing module to address voltage decay of the signal using a stored voltage offset.

Although the example implementations have been described in language specific to structural features and/or methodological acts, it is to be understood that the implementations defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as example forms of implementing the claimed features.

What is claimed is:

1. An input device comprising:

an outer surface configured to receive an application of pressure by an object;

a pressure sensor and haptic feedback mechanism having one or more piezos configured to detect and quantify an amount of the application of the pressure to the outer surface by the object, the one or more piezos configured to output a signal indicating the quantified amount of the pressure; and

a pressure sensing and haptic feedback module configured to receive the signal from the one or more piezos indicating the quantified amount of the pressure and control the haptic feedback of the pressure sensor and haptic feedback mechanism by energizing the one or more piezos based at least in part of the quantified amount of pressure, the pressure sensing and haptic feedback module including a capacitor that takes as an input the signal from the one or more piezos, the capacitor configured to be reset to address voltage decay of the signal using a stored voltage offset by the pressure sensing and haptic feedback module.

2. An input device as described in claim **1**, wherein the pressure sensor and haptic feedback mechanism includes a backer that deflects in response to a pulling motion of the one or more piezos due to the energizing of the one or more piezos.

3. An input device as described in claim **2**, further comprising a spacer configured to route the amount of pressure applied to the outer surface for application at a generally central region of the backer.

4. An input device as described in claim **1**, wherein the outer surface is formed as part of a trackpad that includes one or more sensors disposed thereon that are configured to detect proximity and movement of the object in relation to the outer surface.

5. An input device as described in claim **1**, wherein the one or more piezos are formed at least in part from a piezo ceramic material, PZT, electroactive polymer, or electromechanical polymer.

6. An input device as described in claim **1**, where in the signal is comprised of a summation of multiple signals received from multiple piezos.

7. A trackpad system comprising:

an outer surface configured to receive an application of pressure by an object and detect movement of the object in relation to the outer surface, the detected movement usable to control a cursor of a computing device;

a pressure sensor and haptic feedback mechanism having a plurality of pressure sensors that suspend the outer surface and are configured to detect and quantify an amount of the application of the pressure to the outer surface by the object, the pressure sensor and haptic feedback mechanism configured to output one or more signals indicating the quantified amount of the pressure; and

a pressure sensing module configured to receive the one or more signals from the plurality of pressure sensors indicating the quantified amount of the pressure detected via one or more piezos and control haptic feedback of the pressure sensor and haptic feedback mechanism by energizing the one or more piezos based at least in part on the quantified amount of pressure, the pressure sensing module including a capacitor that takes as an input the signal from the plurality of pressure sensors, the capacitor configured to be reset as part of the pressure sensing module to address voltage decay of the signal using a stored voltage offset.

8. A trackpad system as described in claim **7**, wherein the plurality of pressure sensors utilize the one or more piezos to detect and quantify the amount of the application of pressure.

9. A trackpad system as described in claim **7**, wherein the one or more signals are summed from the plurality of pressure sensors.

10. A trackpad system as described in claim **7**, wherein the one or more signals are received individually by the pressure sensing module from respective ones of the plurality of pressure sensors.

11. A trackpad system as described in claim **10**, wherein the one or more signals are usable to determine a relative location of the object in relation to the outer surface by the pressure sensing module.

12. A trackpad system as described in claim **10**, wherein the one or more signals are usable to determine a relative location of the object in relation to the other surface by the pressure sensing module, and wherein the relative location of the object is calculated through triangulation of the one or more signals.

13. A trackpad system as described in claim **10**, wherein the one or more signals include bipolar voltages that are measured differentially using diodes of the pressure sensing module.

14. An input device comprising:

an outer surface configured to receive an application of pressure by an object;

a pressure sensor configured to detect and quantify an amount of the application of the pressure to the outer surface by the object, the pressure sensor configured to output a signal indicating the quantified amount of the pressure;

a haptic feedback mechanism configured to provide haptic feedback using at least one piezo; and

a pressure sensing module configured to receive the signal from the pressure sensors indicating the quantified amount of the pressure and control the haptic feedback of the haptic feedback mechanism by energizing the at least one piezo based at least in part on the quantified amount of pressure, the pressure sensing module including a capacitor that takes as an input the signal from the pressure sensor, the capacitor configured to be reset as part of the pressure sensing module to address voltage decay of the signal using a stored voltage offset.

15. An input device as described in claim **14**, wherein the pressure sensor employs the at least one piezo of the haptic feedback mechanism to detect and quantify the amount of the application of the pressure.

16. An input device as described in claim **14**, wherein the haptic feedback mechanism includes a backer that deflects in response to a pulling motion of the at least one piezo due to the energizing of the at least one piezo.

17. An input device as described in claim **16**, further comprising a spacer configured to route the amount of pressure applied to the outer surface for application at a generally central region of the backer.

18. An input device as described in claim **14**, wherein the outer surface is formed as part of a trackpad that includes one or more sensors disposed thereon that are configured to detect proximity and movement of the object in relation to the outer surface.

19. An input device as described in claim **14**, wherein the at least one piezo is formed at least in part from a piezo ceramic material, PZT, electroactive polymer, or electromechanical polymer.

20. An input device as described in claim **14**, wherein the pressure sensing module is configured to energize the at least one piezo in response to the quantified amount of pressure exceeding a threshold amount of pressure.

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